Reclamation Research Unit
Department of Land Resources and Environmental Sciences
Montana State University
106 Linfield Hall, Bozeman, MT 59717-2910
Phone: 406/994-4821 FAX: 406/994-4876
http://www.montana.edu/reclamation

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Date: February 17, 2004

To: Sue Sillick

From: Stuart Jennings

Re: Revisions and Incorporation of Technical Panel inputs to :
Progress Report 2. *Evaluation of Organic Matter Addition and Incorporation on Steep Cut slopes, Phase II: Test Plot Construction and Performance Monitoring*

The second progress report of Phase II of the above referenced project is attached. The attached narrative describes the successful construction of research plots along U.S. Highway 2 near Libby, Montana. The plots were constructed under budget and on schedule.

Construction of test plots at the Colstrip South project did not occur. No expenditure of funds occurred and no progress has been made. Resolution of the current problem is discussed.

As a significant attachment to this progress report, the draft Final Report narrative for construction of the test plots at Happys Inn is included. This product is not due until November 2006 in final form as the Final Report. The preliminary draft provided was compiled while the plot construction experience was fresh in mind. It is our intent to compile data collected during the project into interim reports during the current quarter given the long duration of the contract. Preparation of the final version of the report will occur during the final quarter (fourth quarter 2006) and will entail compiling and synthesizing the interim summaries. This second quarterly report contains the first section of text for the Final Report.

Quarterly Progress Report #2
For the period October 1, 2003 – December 31, 2003

EVALUATION OF ORGANIC MATTER ADDITION AND INCORPORATION ON STEEP CUT SLOPES

Phase II: Test Plot Construction and Performance Monitoring

Prepared For:

Montana Department of Transportation
P.O. Box 201001
Helena, MT 59620-1001

Prepared By:

Reclamation Research Unit
Department of Land Resources and Environmental Sciences
Montana State University
Bozeman, MT 59717-2910

January 2004

Task Analysis and Discussion

Construction of research test plots along the U.S. Highway 2 Right-of-way near Happys Inn occurred during the week of October 20-24, 2003. The plots were successfully constructed and seeded. Monitoring of the resulting vegetation will begin in the Spring of 2004. Further discussion is presented in this report under the heading Task H, Plot Construction.

Construction of research test plots at the Colstrip South project during the quarter did not occur as planned. Evaluation and discussion of this problem is presented in this report under the heading Problems and Resolution.

No activity occurred during the quarter on the project tasks: A (Literature Review), B Site Selection, D (Equipment Identification), E (MDT Coordination Meeting), F (Preconstruction Meeting), G (Construction Coordination), or J, K and L (Monitoring).

Task C Experimental Design

In parallel with the Phase II proposal, the experimental design was finalized prior to research plot implementation. Two dissimilar glacial parent materials were selected for implementation of the research plots. Both supported very little vegetation. The glacial silt parent material was light colored, fine textured and had little rock content. The alluvial rock parent material was very coarse with abundant rounded rock fragments in excess of 2 inches in diameter and a mean minimum rock content (> 2 mm) of 63.5 percent. At each site, five experimental plots were constructed: two inch compost blanket, one inch compost blanket, 2 inches of compost incorporated into the top 4 inches of soil, 1 inch of compost incorporated into the top 4 inches of soil and a control that had no compost added. Seed for the test plots was selected and applied by Phil Johnson of Montana Department of Transportation (MDT).

Task H Plot Construction

Ten test plots were constructed during the week of October 20-24, 2003. Plot construction was accomplished by contractors hired by MSU and facilitated by personnel from the MDT Maintenance Section House at Crystal Creek and Phil Johnson representing MDT Headquarters in Helena. Compost was obtained from EKO Compost from Missoula prior to plot construction and stockpiled at Crystal Creek. Compost application has performed by Quality Landscape Seeding of Belgrade, Montana using a pneumatic blower truck. Incorporation of compost into the soil was performed by Arrowhead Reclamation of Whitehall, Montana using a modified snowcat. Further discussion of plot construction is included in the attached narrative.

Task I Site Sampling

Soil samples were collected from each of the experimental plots prior to compost application, tillage and seeding. Soils were collected to establish the baseline soil condition in which vegetation was previously unable to establish. Soil samples will again be collected during the second year of monitoring to demonstrate the effect of treatment. The samples collected have been dried, sieved to determine coarse fragment content and submitted to an analytical laboratory. Chemical analysis of the soil has not been completed and will be reported in the third quarterly report due in April 2004.

Task J Year 1 Monitoring

This task has not been initiated.

Task K Year 2 Monitoring

This task has not been initiated.

Task L Year 3 Monitoring

This task has not been initiated.

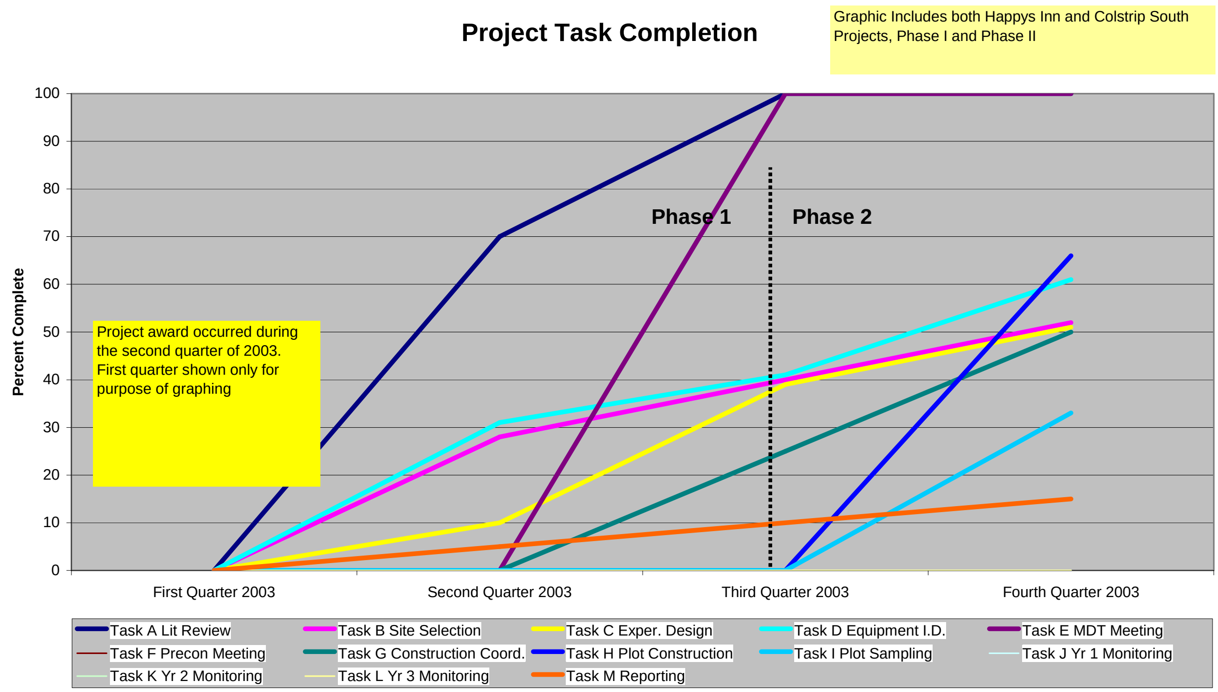
Task M Reporting

This second quarterly report satisfies the periodic reporting requirement of the contract. A Final Report will also be completed in 2006 summarizing the research findings. The first installment of text for the Final Report is attached to this progress report and summarizes the construction of test plots at the Happys Inn research site.

Schedule and Degree of Completion—Happys Inn Research Site

The Happys Inn Research Site was successfully constructed during the fourth quarter of 2003 on schedule. Expenses related to plot construction were somewhat less than expected. A substantial cost savings was realized by deletion of the regrading task identified in the proposal and relocation of the research site. Regrading was not required at either site constructed near Happys Inn. Site sampling occurred prior to plot construction. Samples have been submitted for laboratory analysis. This task will be 50% complete when the analytical results are returned from the lab. The second half of this task will be competed during 2005 monitoring.

Task Description (Happys Inn)	***Budgeted Total Phase II***	***Proposed Schedule***	***Actual Schedule***	***Degree of Completion***	***Estimated Expenditure***
Task C Experimental Design	$277.95	Fourth Quarter, 2003	Fourth Quarter, 2003	100%	$277.95
Task H Plot Construction	$30,082.00	Fourth Quarter, 2003	Fourth Quarter, 2003	100%	$19,500
Task I Site Sampling	$4852.91	Fourth Quarter, 2003 and Third Quarter 2005	Fourth Quarter, 2003; Analytical results First Quarter 2004; 2005	30%	~$1500
Task J Year 1 Monitoring	$7551.12	Spring and Fall, 2004	NA	0%	0
Task K Year 2 Monitoring	$9823.84	Spring and Fall, 2005	NA	0%	0
Task L Year 3 Monitoring	$9823.84	Spring and Fall, 2006	NA	0%	0
Task M Reporting	$9903.27	Quarterly and Final Report, Fall 2006	ongoing	15%	$3000



Problems and Resolution

During September 2003, phone conversations between Phil Johnson and MDT Construction personnel based in Miles City revealed some level of reluctance on the part of the Miles City staff to participate in a research project at the Colstrip South location. The availability of a research site remains uncertain. Effort has been expended by Phil Johnson to bring resolution to the issue. Resolution of the problem is expected to occur during the first quarter of 2004 with plot construction occurring during late April, 2004. A phone conversation with Phil Johnson (Jan. 12, 2004) confirmed that he intends to take the lead in bringing resolution to the problem through MDT administrative processes. No participation by MSU is required in bringing resolution to the problem.

Accomplishments

- Test plots were constructed at the Happys Inn research site on alluvial rock and glacial silt parent materials on steep slopes.

- Demonstration of the effectiveness of the pneumatic blower truck, modified snowcat and Land Tamer all wheel drive vehicle were completed.

- A video tape showing plot construction activities was prepared and distributed to MDT and to contractors participating in plot construction.

Fiscal Expenditure

Amount Spent by budget category:

Cost Category	***Spent Last Quarter ($)***	***Spent during the current quarter ($)***	***Total Spent ($)***
Labor and Benefits	$2004.61	$8163.59	$10,168.20
Operational Expenses	$112.06	$1194.78	$1306.84
Subcontracted Services	0	$9777.11	$9777.11
Indirect Charges	$ 375.83	$2618.51	$2994.34
Total Spent	***$2492.50***	***$21,753.99***	***$24,246.49***

Total Project Award $108,975

Amount Remaining $84,728.51

Progress Report
Attachments

Preliminary Draft

Final Report Text Compiled during the period 10/1/03-12/31/03

***Preliminary* Table of Contents**

Page

1.0 Introduction

Text to be completed during fourth quarter 2006

2.0 Research Site Selection

2.1 Happys Inn Research Sites

One of the objectives for this research project was to investigate the application and incorporation of compost on steep cut slopes on three general types of geologic materials including:

1. Coarse textural class valley fill/glacial outwash type materials,
2. Fine textural class materials derived from glacial silt, lake bed sediments and loess, and
3. Fort Union Group shale units typical of eastern Montana plains.

All of these soil materials on steep slopes are encountered by the Montana Department of Transportation (MDT) during roadway construction and reconstruction. All have previously been shown to be difficult to revegetate leading to increased maintenance costs and increased potential for degradation of surface waters by erosion and sedimentation. Research projects to date have been initiated only on the first two material types, both of which are located in the vicinity of Happys Inn between Libby and Kalispell on U.S. Highway 2.

An initial site reconnaissance was conducted May 6-7, 2003, at which time two sites were tentatively selected at Mile Posts (MP) 67 and 69 on U.S. Highway 2, approximately 60 km east of Libby, Montana (Figure 1). The MP67 site was comprised of glacial till with abundant boulders and cobbles in a fine textured matrix. This site was highly eroded and over steepened. Gullies up to approximately 1 m deep were present. Regrading the slope would have been required to eliminate the rills and gullies and to return the slope to a 50 percent gradient. Subsequent discussions indicated that the resources to regrade and remove several thousand cubic meters of material were not available and an alternative site was selected at MP77 (Middle Thompson Lake). Although the MP77 site was less steep than the desired 50 percent slope, it was composed of fine textured glacial lakebed soils that have proven very difficult to successfully revegetate. Materials at the MP69 site (Loon Lake) were very coarse textured and required no regrading.

2.1.1 Physiographic Conditions

Both research sites are in the forested, mountainous terrain of northwestern Montana. Elevations range from about 1012 m (3320 feet) at the outlet of Loon Lake to 1841 m (6040 feet) at nearby Rogers Mountain. Drainage into and out of Loon Lake is via the Fisher River that flows west and north to a confluence with the Kootenai River west of Libby, Montana. Drainage from

Middle Thompson Lake flows to Lower Thompson Lake, the headwater of the Thompson River and thence to the confluence with the Clark Fork River near Thompson Falls, Montana.

The area is underlain by Belt Group metasedimentary rocks, including the Wallace Formation, Missoula Group and Ravalli Group (Ross et. al., 1955). Much of the present topography is the result of both local and cordilleran glaciation (Alden, 1953). Morainal debris, till, outwash, and lake sediments are present in the vicinity and exposed in numerous cut slopes along U.S. Highway 2.

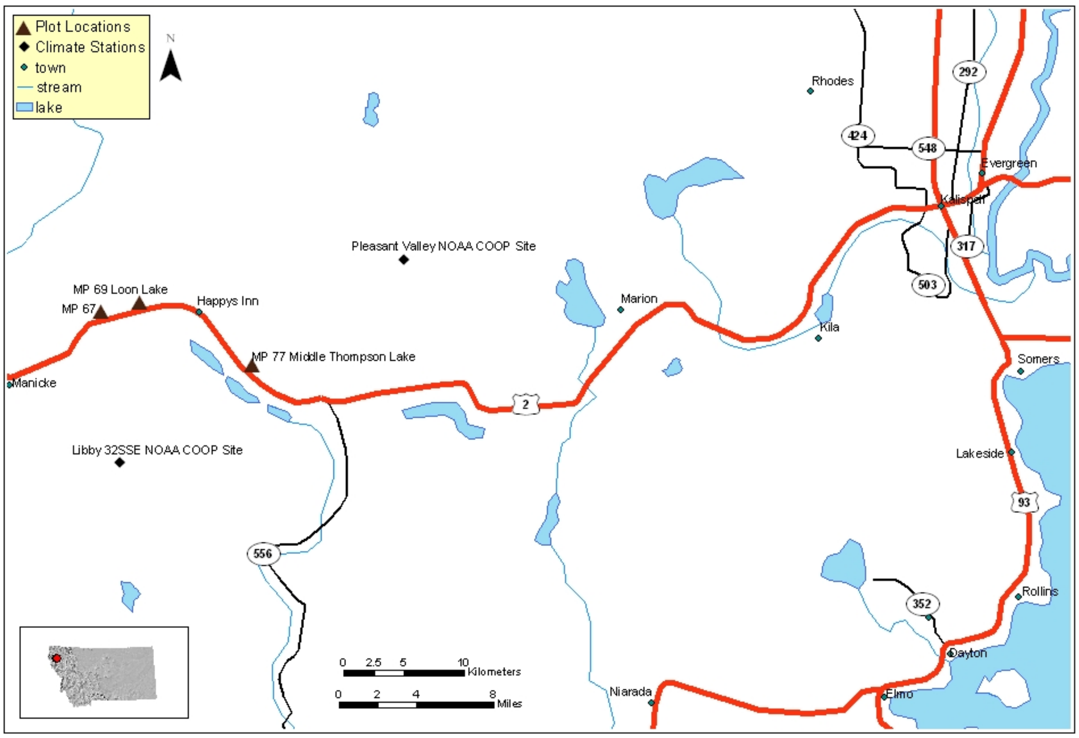


Figure 1. Happys Inn research site locations.

2.1.2 Climatic conditions

Climatic data is available from two stations near the research sites: 1) Libby 32 SSE (station 245020), and 2) Pleasant Valley (station 246576). These stations are approximately 13 km southwest and 16 to 18 km northeast of the research sites respectively (Figure 1). Elevation at both of these climatic stations is 1097 m versus approximately 1036 m at the research sites. The distribution of annual precipitation is very similar at the two climatic stations. Approximately 60 percent of the precipitation occurs during the October through March period with January receiving the greatest monthly precipitation for the year. June receives the greatest precipitation during the growing season, while July, August, and September are the driest months of the year (Figure 2). Most precipitation in the November through April period occurs as snowfall with some accumulated snow depth occurring during these months. Mean annual precipitation for the Libby 32 SSE climate station is 63.4 cm (24.96 inches) while the Pleasant Valley station reports 47.7 cm (18.78 inches) of annual precipitation.

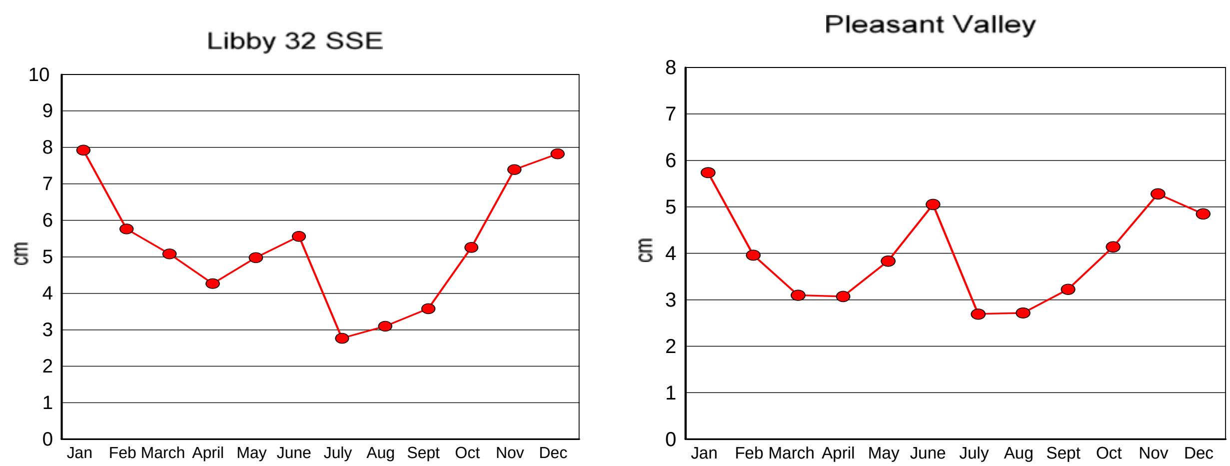


Figure 2. Monthly precipitation for NOAA stations 245020 (Libby 32 SSE) and 246576 (Pleasant Valley).

The mean annual temperature at the two NOAA sites is 4.7 degrees C (40.5 degrees F). Average maximum temperatures range from -1.2 degrees C (29.9 degrees F) in January to 26.1 degrees C (79.1 degrees F) in July. Average minimum temperatures remain less than 0° C in the October through April period (Figure 3).

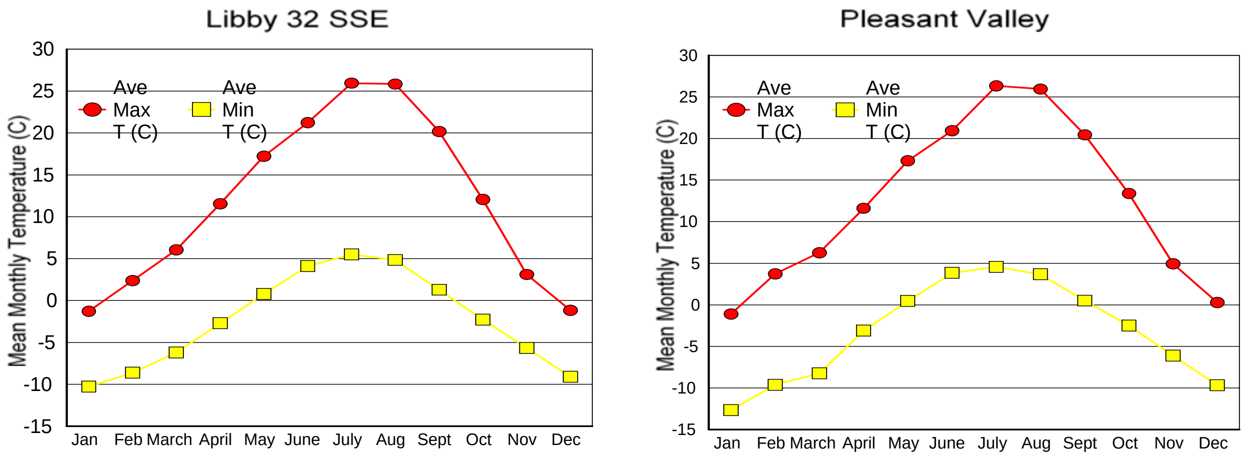


Figure 3. Mean monthly maximum and minimum temperatures at climate stations near the Happys Inn research sites.

The MAPS program (Caprio et. al., 2001) was used to estimate monthly evapotranspiration (Figure 4). All values for the two sites were identical except for September, with July and August exhibiting the greatest evapotranspiration rates of 14.5 and 11.7 cm respectively. Potential evapotranspiration is notably greater than mean monthly precipitation during July and August.

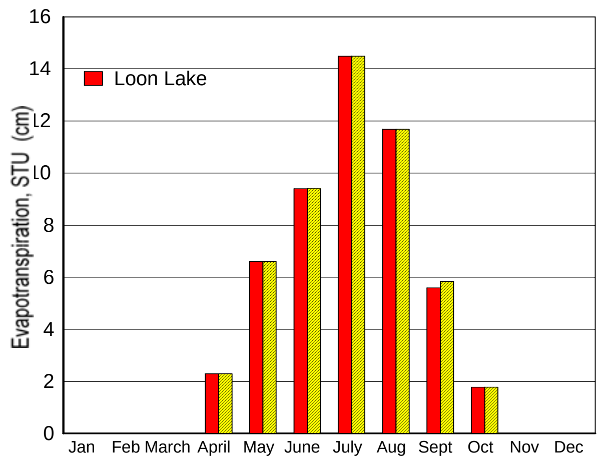


Figure 4. Mean monthly evaporation for Happys Inn research sites. Values determined through MAPS program by Caprio (1971) solar-thermal unit method.

In general, precipitation should not be limiting at either of the Happys Inn research sites. However, the combination of south aspects, droughty soil conditions caused by either excessive runoff (silt dominated site) or low water holding capacity (sand and rock dominated site), low growing season precipitation during July, August, and September, and moderately high evapotranspiration rates in July and August has the potential to produce conditions unfavorable for plant development.

2.1.3 Existing Vegetation

Vegetation in areas adjacent to the highway cut slopes selected for this study consists of typical forest community species found in northwestern Montana. The coniferous over-story is dominated by Douglas fir (*Pseudotsuga menziesii*[1]), western larch (*Larix occidentalis*), and ponderosa pine (*Pinus ponderosa*) while the under-story contains many forbs, grass, and shrubs. Most, if not all, adjacent areas have been logged at least once. Many of the native species would be difficult to establish on the generally south aspect steep cut slopes that lack organic matter. Virtually none of the native species had volunteered on the cut slopes at the research sites constructed in 2000. Noxious weeds have begun to encroach along the margins of the sites, especially spotted knapweed *(Centaurea maculosa*). Vegetation conditions at the Loon Lake site (MP69) prior to implementation of the compost treatments are presented in Table 1. The Middle Thompson Lake site was essentially barren of any vegetation. Table 2 reports the ground cover observed at the Middle Thompson Lake site prior to treatment.

[1] All nomenclature in this report is based on Hitchcock and Cronquist 1973 unless otherwise noted.

Table 1. Species composition and abundance at the Loon Lake research site (MP69) prior to treatment.

Common Name	**Scientific Name**	**Abundance**
Sheep fescue*	*Festuca ovina*	+
Slender wheatgrass**	*Agropyron trachycaulum*	-
Sweetclover	*Melilotus sp*	-
Spotted knapweed	*Centaurea maculosa*	-
Alfalfa	*Medicago sativa*	#
Mullein	*Verbascum thapsus*	#
Canada wildrye	*Elymus canadensis*	#
Blue flax	*Linum lewisii*	#
Lodgepole pine	*Pinus contorta*	#

+ = 2 to 5% canopy cover class
- = 1 to 2% canopy cover class
= < 1% canopy cover class

* Sheep fescue comprises 90% of plant density and canopy coverage. The fescue averages about 3 plants per square foot across all plots. Stunted growth was observed - diameter of leaf spread across canopy averages 2 to 5 inches.

** Agropyron species [primarily slender wheatgrass] represents about 1 plant per square foot across all plots with only 1 to 3 culms [stems] per plant.

Table 2. Ground cover observed at the Loon Lake site (MP 69) prior to treatment.

Vegetation and rock cover observed	Distribution
Total plant canopy cover [all species]	8%
Basal cover [all species]	1.5%
Ground litter cover	1.0%
Rock cover: <0.5 inch diameter	25%
Rock cover: 0.5 - 2 inch diameter	55%
Rock cover: 2-6 inch diameter	15%
Rock cover: > 6 inch diameter	3%

2.2 Colstrip South Research Site

To be completed during 2004 and contingent of resolution of site availability concerns.

3.0 Experimental Design

Five research plots have been established at both MP69 and MP77 sites that represent two of the three types of geologic materials desired for this study (Table 3). Treatments included:

- Tillage and broadcast seeding only (controls);
- 2.5 cm compost application incorporated to 10 cm, broadcast seeding;
- 5.1 cm compost application incorporated to 10 cm, broadcast seeding;
- 2.5 cm compost application (blanket), broadcast seeding; and
- 5.1 cm compost application (blanket) with broadcast seeding.

Table 3. Plot treatments for the MP69 and MP77 research sites.

Site	Plot Number	Treatment	Mean Overall Gradient (%)	Mean Slope Length (m)
MP77 *Middle Thompson Lake* Lakebed Silt Dominated Material	1	Control, no compost, chisel plowed	34.5	18.3
	2	2.54 cm compost, incorporated with chisel plow	34.0	17.4
	3	5.08 cm compost, incorporated with chisel plowed	35.0	17.2
	4	2.54 cm compost blanket	37.0	19.8
	5	5.08 cm compost blanket	38.0	15.9
MP69 *Loon Lake* Coarse Textural Class Material	6	Control, no compost, chisel plowed	49.0	15.2
	7	2.54 cm compost, incorporated with chisel plow	48.5	15.2
	8	5.08 cm compost, incorporated with chisel plow	45.0	15.2
	9	2.54 cm compost blanket	43.5	15.2
	10	5.08 cm compost blanket	44.0	15.2

4.0 Research Plot Construction

The experimental design for this project seeks to evaluate both the equipment used for application and incorporation of compost on steep slopes and to subsequently evaluate the effect of the compost treatments on vegetation performance. The following subsections describe the implementation of study sites at MP69 (Loon Lake) and MP77 (Middle Thompson Lake).

All compost application was completed using a blower truck (Express Blower/Rexius Model EB-30). Compost thickness was monitored during the application process so that an even distribution of compost was achieved on each treatment plot. Because of scheduling problems, all compost application was completed prior to any incorporation or tillage. Hence, the compost blanket treatments (plots 4, 5, 9, and10) were placed directly on the untilled substrate. All other plots were chisel plowed. A considerable amount of additional plot tillage was provided by the snowcat track grousers.

4.1 MP69 (Loon Lake) Research Site

The MP69 site is located on the north side of U.S. Highway 2 immediately northwest of Loon Lake (Figure 5). The site is characterized by very coarse textural class material with abundant boulders and cobbles (Figure 6). Mean rock content (> 2 mm) was 63.5 percent (Table 4). All plots at this site were 15.24 m square (232.2 m^2) with 3 m buffer zones between plots (Figure 7).

Figure 5. Location of MP69 (Loon Lake) research site.

Figure 6. MP69 (Loon Lake) research area preconstruction conditions, Plot 8.

Table 4. MP69 (Loon Lake) preconstruction physical site characteristics.

Plot	Treatment	Mean Overall Gradient (%)	Mean Slope Length (m)	Rock Content > 2mm (%, mass basis[1])	USDA Textural Class
6	Control, no compost	49.0	15.2	70.9	Tbd
7	2.54 cm compost, incorporated	48.5	15.2	62.6	Tbd
8	5.08 cm compost, incorporated	45.0	15.2	66.0	Tbd
9	2.54 cm compost blanket	43.5	15.2	47.7	Tbd
10	5.08 cm compost blanket	44.0	15.2	70.5	Tbd

[1] Cobble and boulder materials were not included in collected samples and therefore actual rock content will be greater than the stated value.

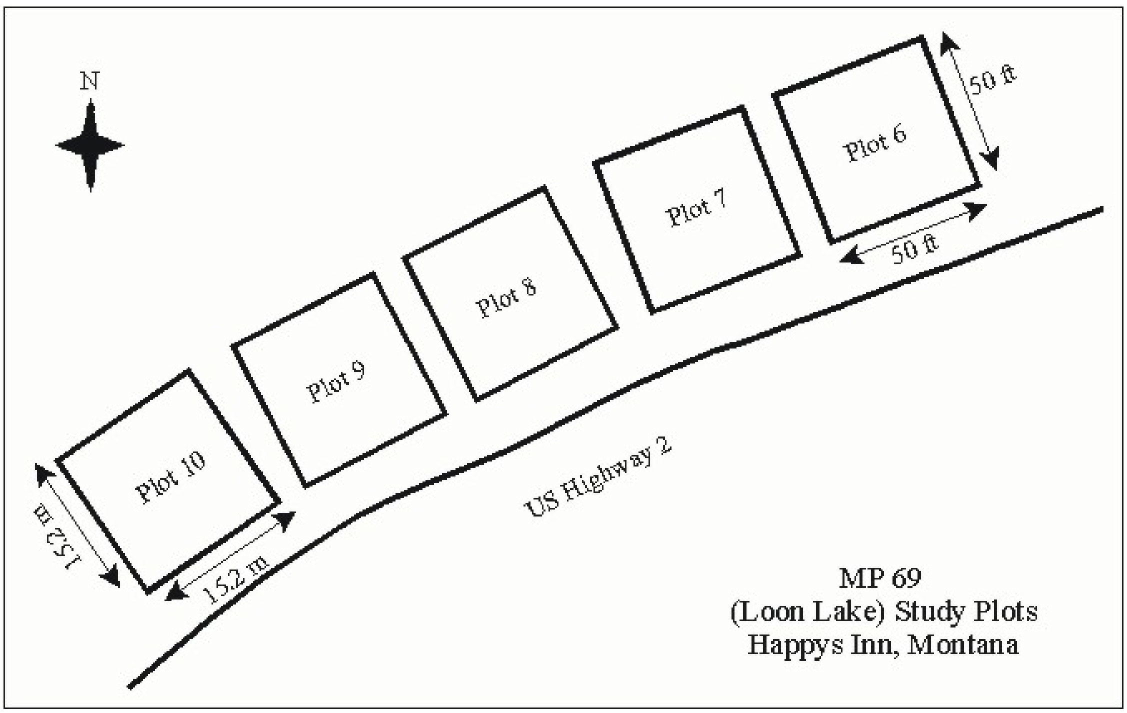


Figure 7. Research plot layouts at the MP69 site.

Compost was applied at this site on October 21, 2003. Due to the very coarse texture, no prior tillage of this site was deemed necessary. Seed was broadcast at a rate of 39 kg/ha. Plots 7 and 9 received 2.5 cm compost blankets while plots 8 and 10 received 5.1 cm blankets. Plots 6, 7 and 8 were chisel plowed on October 23, 2003.

4.2 MP77 (Middle Thompson Lake) Research Site

The MP77 site is located along the north side of U.S. Highway 2 adjacent to Middle Thompson Lake (Figure 8). Geologic materials consist of fine textural class sediments that are assumed to be glacial lake sediments. Alden (1953) stated that "Cuts on the new grade of U.S. Highway No. 2 along the north side of the Thompson Lakes, examined in June 1937, gave fine exposures (at about 3,400 ft above sea level) of 20 to 25 ft of finely laminated buff to brownish, rather plastic lacustrine silt. In some of the cuts in these beds have been disturbed by slumping and in some the silt overlies gravel. The silt was evidently deposited in a glacial lake bordering the front of the melting Cordilleran ice." Typically, these materials have very little rock content (Table 5). The lacustrine silts have proven troublesome to revegetate following construction and vegetation was sparse at this site with a notable accumulation of sediment in roadway drainage ditches (Figure 9). One of the primary erosion mechanisms occurring in these silts appears to be the slumping of saturated surface layers that overlie frozen substrate during spring thaw cycles.

Figure 8. Location of research plots at MP77 site, adjacent to Middle Thompson Lake.

Figure 9. Research Plot 1 at the MP77 site prior to plot implementation. Note accumulated sediment in ditch, rills, and the general lack of vegetation cover.

Table 5. MP77 (Middle Thompson Lake) preconstruction physical site characteristics.

Plot	Treatment	Mean Overall Gradient (%)	Mean Slope Length (m)	Rock Content > 2mm (%, mass basis)	USDA Textural Class
1	Control, no compost	34.5	18.3	1.2	Tbd
2	2.54 cm compost, incorporated	34.0	17.4	0.19	Tbd
3	5.08 cm compost, incorporated	35.0	17.2	0.66	Tbd
4	2.54 cm compost blanket	37.0	19.8	5.11	Tbd
5	5.08 cm compost blanket	38.0	15.9	1.81	Tbd

Research plots at this site are 12.2 m wide with lengths ranging from 17.2 to 19.8 m. All buffer strips are 3 m except that between plots 2 and 3 that is 9.1 m wide (Figure 10). The extra width of the buffer between plots 2 and 3 was included to avoid an area that had some established vegetation and which also would have resulted in a short plot length. The mean plot area at this site is 215.9 m^2.

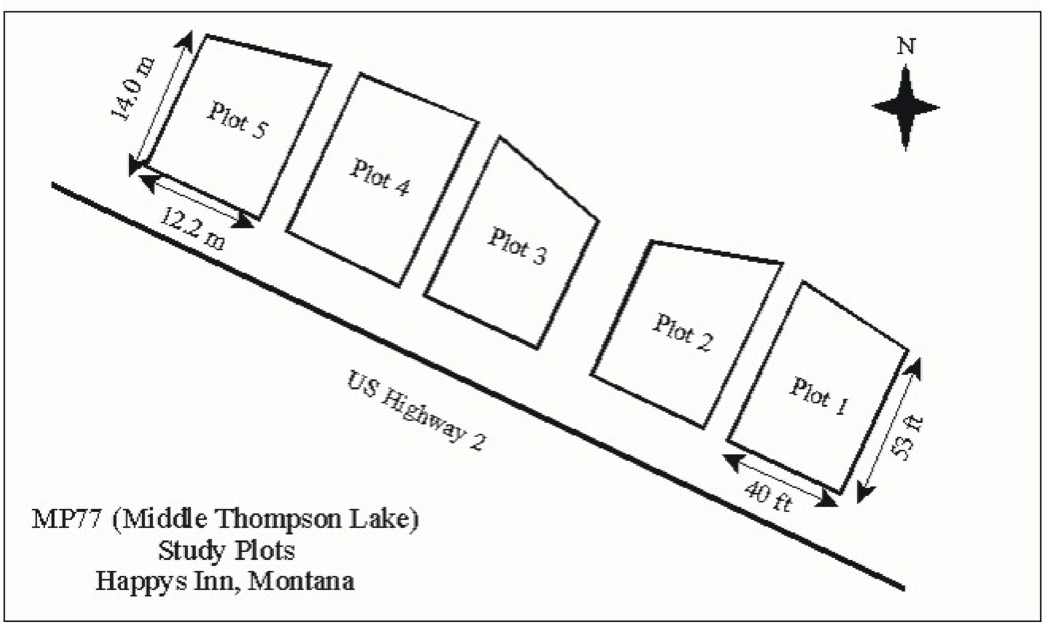


Figure 10. Plot layout at the MP77 research site.

4.3 Seeding

All plots at both MP69 and MP77 were seeded with the same seed mix (Table 6) which was obtained from Bruce Seed Farm, Inc. located near Townsend, Montana. Seed was applied using a hand operated broadcast seeder at a total rate of 0.91 kg per plot. This rate is the approximate equivalent of 39 kg/ha. The seed was applied in two applications, the first on bare substrate and the second following application of 1.3 cm of compost over the first seed application. The remaining compost was applied over the second seed application. The seeding scenario acknowledges the fact that a portion of the applied seed will be placed deeper than desired and therefore this portion may have poor emergence. An extra 0.45 kg of seed was specifically applied to plot 7 at MP69 following tillage. This was done due to a large disturbance to a portion of this plot that occurred when a track broke on the snowcat during the tillage operation. The seed mix was free of noxious or restricted weed seed. Since no compost was applied to the control plot, seed was applied by a hand broadcast seeder directly to the mineral soil following tillage.

Table 6. Seed mix species used at the MP69 and MP77 research sites.

Species	**Common Name**[1]	**Variety**	**Percent of Mix (*pure live seed* basis)**
Elymus trachycaulus ssp. trachycaulus	Slender Wheatgrass	Pryor	7.62
Elymus hoffmanii	Hybrid Wheatgrass	Newhy R/S	20.65
Elymus canadensis	Canada Wildrye	V.N.S.	12.70
Bromus marginatus	Mountain Brome	Bromar	12.18
Pseudoroegneria spicata ssp. Spicata	Bluebunch Wheatgrass	Goldar	12.70
Poa ampla	Big Bluegrass	Sherman	2.66
Nassella viridula	Green Needlegrass	Lodorm	7.38
Elymus lanceolatus ssp. Psammophilus	Streambank Wheatgrass	Sodar	12.85
Festuca ovina	Sheep Fescue	Covar	2.61
Festuca arundinacea	Tall Fescue	Fawn	5.08

[1] Seed label contained only common name and variety.

4.4 Compost Mixing

A preliminary evaluation of the effectiveness of the methods used to incorporate compost suggests that incorporation/mixing on the fine textured lake bed sediments at MP77 was very good. A combination of the tilling action of the snowcat grousers and the chisel plow resulted in a relatively uniform incorporation depth with very little unmixed compost visible. Effective tillage depth was close to the desired 10 cm. Incorporation on the coarse textured materials at MP69 was inconsistent, due in large part to the difficulty of controlling the equipment as it rode over boulders. In areas were traction was lost, the snowcat grousers moved much material down hill creating mixed zones notably deeper than the desired 10 cm. In the "spin out" areas where the material was removed, little compost remained. There were areas near the top break of slope where the chisel plow was ineffective due to the limitations of the 3-point hitch which pulled the plow out of the substrate as the front of the snowcat nosed down on the more level terrain above the cut slope. This may not be a problem on longer slopes where the area affected by the radical break in slope would comprise only a small portion of the total area.

4.5 Equipment Evaluation

The equipment utilized for this study was limited. It included:

1. Express Blower (Rexius) blower truck model EB-30;
2. LMC model 3700C snowcat using Pisten Bully 2.5 m wide steel tracks and a standard agricultural 3-point quick attach hitch; and
3. A 2.5 m wide 3-point mounted, spring shanked Graham Hoeme chisel plow.

The performance of this equipment, along with one demonstration unit (Land Tamer) is discussed in the following subsections.

4.5.1 Blower truck

The blower truck experienced no difficulties applying compost to the research plots (Figure 11). The maximum length of the research plots was only 10 to 20 percent of the capability of the truck (standard hose length is 111.6 m or 366 feet) and no clogging of feeders or blower hose occurred. Minor hand shoveling inside the truck box was required to feed compost to the walking floor when the unit was near empty. This was apparently caused by the tilt of the unit produced by stationing it partially in the borrow pit to maintain a clear traffic lane. Compost application was timed for several plots. Approximately 10 minutes was required to apply a controlled 1.3 cm compost layer on each plot and an additional 15 to 20 minutes to apply the remaining 3.8 cm of compost on the 5.1 cm treatments for an approximate rate of 0.05 ha/hr (Table 7). These rates should not be construed as the expected rate on a full scale project. Due to the size of the research plots, more time was required to ensure the applied compost was within plot boundaries. The application of two specific compost layers increased application time by about 10 percent. Manufacturer literature suggests normal application rates of 0.76 to 1.53 m^3 (1 to 2 cubic yards) per hour. At the higher rate, a 5.08 cm compost blanket would be applied at 0.18 ha/hr.

Figure 11. Express Blower Model EB-30 applying compost at the MP77 site.

Table 7. Rate of compost application observed during plot construction.

Plot Number	Plot Area (square m)	Applied Thickness (cm)	Application Time (min:sec)
2	212	1.3	9:00
2	212	3.8	19:00
4	242	1.3	11:00
5	193	1.3	15:30
10	232	1.3	10:30
10	232	3.8	15:20

4.5.2 Snowcat

The snowcat utilized for this project was a modified LMC 3700C (Figure 12). This unit is powered by a Caterpillar 3208 diesel engine rated at 165 kw (225 hp) and weighs approximately 8160 kg (18,000 lbs). Modifications to this unit were:

Reinforced undercarriage,
Upgraded cooling system,
Solid rubber boggy wheels,
Pisten Bully drive sprockets and 2.5 m wide steel tracks,
Rear 3-point quick hitch,
Front 3-point brackets to mount broadcast seeder, and
MSHA certified ROPS canopy.

Figure 12. Modified LMC 3700C initiating tillage on plot 8, MP69 site.

The snowcat had more than sufficient power to use the chisel plow while traversing upslope at both research sites. The performance of the unit was excellent on the fine textured materials at MP77. Traction was very good in the silt dominated material at this site and the operator had very good control of induced track slippage (for additional tillage/mixing action) and very good maneuverability. Operation was equally good while traversing up-down or across slope at this site.

The performance of the unit at the MP69 site was compromised by the numerous boulders and large cobbles. While the snowcat had sufficient power and traction overall, the rigid suspension resulted in traction loss when riding up on boulders with a resulting excess of track slippage. In addition to undesirable effects on compost incorporation (moved an excessive amount of compost down-slope), it made steering control more difficult. An effort to traverse across the slope at MP69 resulted in a broken track. This was likely the result of both the weight of the machine applying excessive pressure on the downhill track boggy wheel guides and the gravel/cobble material that accumulated in the track.

The snowcat 3-point hitch arrangement performed very well in all situations except when breaking over the top of the cut slope onto native slope. This radical attitude transition exceeded the travel limit of the 3-point hitch and tended to pull the implement out of the soil. This situation should be expected with any type of 3-point mounted equipment. As noted previously, this would likely be a minor problem on a full-scale project. The 3-point system allowed the implement to be raised at any time, therein enhancing maneuverability and expediting production by allowing uninhibited backing on short slopes.

4.5.3 Chisel Plow

The Graham Hoeme chisel plow utilized for this study worked equally well in both coarse and fine textural classes of material (Figure 13). Shank spacing was set at 0.35 m (1.1 ft) for the 2.4 m (8 ft) wide implement. Potential tilling depth was well in excess of the specified 10.2 cm (4 in) compost incorporation depth for this project. No breakage or other problems were encountered with this unit. It is likely that a wider implement of similar design could have been utilized, especially at the MP77 site.

Figure 13. Graham Hoeme 2.4 m (8 ft) spring shanked chisel plow at MP69.

4.5.4 Land Tamer

PFM Manufacturing provided a standard industrial LT model for demonstration purposes at the MP69 site (Figure 14). This unit is a diesel powered eight-wheeled vehicle utilizing a hydrostatic drive. While this machine had no trouble traversing the 50 percent slopes at MP69, either on the contour or at an angle, it suffered from problems similar to the snowcat. Its rigid suspension limited wheel contact when riding over large cobble and boulders. The resulting loss of traction was sufficient to prevent direct traverse up slope at this site even without any tillage implements. The Land Tamer was not demonstrated at the MP77 site. It is the authors' opinion that this unit would have performed acceptably well on the silt-dominated materials using a small tillage implement.

Figure 14. Land Tamer industrial model LT adjacent to MP69 research site.

4.5.4 Equipment Performance Summary

The blower truck utilized for this study has the capability to apply compost or similar materials to nearly any slope up to a steepness at which the applied materials will slough off due to gravity. The blower has sufficient power to blow compost through at least 100 m of hose and likely considerable farther. The factory specification for the unit used (EB-30) suggests full-scale application rates could be double the rates at which the compost was applied to the research plots. Highway construction contractors will have to evaluate this type of equipment as they would any other: production versus cost. The blower trucks will be capable of applying compost where other means are lacking or are inefficient.

The use of snowcat type equipment for tillage on steep slopes is viable but productivity and job quality may suffer if the construction site contains abundant cobble and boulders. Conditions at MP69 were close to the limit of the snowcat used. It is apparent that some type of suspension would be very beneficial for work on similar slopes containing considerable cobble and boulders.

Pisten Bully introduced a new "dry ground" model in 2003. This is the Pisten Bully 100 Flexmobil that does include an advanced suspension (Figure 15). Although this machine is less powerful than the modified LMC 3700C used in this study, it may be better adapted to conditions such as found at MP69.

Figure 15. Pisten Bully model 100 Flexmobil (Kassbohrer Gelandefahrzeug AG photo).

5.0 Sampling and Analysis

Soil samples were collected from all plots prior to construction. In addition, samples of the stockpiled compost were collected prior to any application.

5.1 Soil Samples

Two composite soil samples were collected from each plot. All samples were collected using identical methodology. The center of each plot was located and from this point, three subsample sites were located at 120 degree intervals on a 3 m radius, with one leg directly down-slope. All samples were collected by trenching the soil pit wall to a depth of 10.2 cm. Each sample consisted of a 3.8 liter (1 gallon) zip lock bag. The primary intent of the two composite samples was to provide sufficient sample volume for all analyses, but it also provided necessary quality control/quality assurance samples. Samples are to be analyzed for numerous parameters including pH, specific conductance (SC), sodium adsorption ratio (SAR), N, P and K, organic matter (OM), C:N ratio, coarse fragment content, and soil textural class (Table 8).

Table 8. Soil sample analyses and methods.

Analysis	Method
Saturated Paste Extract pH	ASA/SSSA[1], 1982: Methods 10-2.3, 10-3.2
Saturated Paste Extract SC	ASA/SSSA, 1982: Methods 10-2.3, 10-3.3
SAR	ASA/SSSA, 1982: Methods 10-2.3, 10-3.4 (cations analyzed by Atomic Absorption Spectrometer-AAS)
NO_3-N	ASA/SSSA, 1982: Methods 33-8.2, 33-8.3
Olsen P	ASA/SSSA, 1982: Method 24-5.4
K	ASA/SSSA, 1982: Method 9-3.1, modified (extract diluted in 0.5 % La_2O_3 with1% HCl & analyzed AAS)
OM	ASA/SSSA, 1982: Method 29-3.5.2, Modified Walkley-Black
Coarse Fragment Content	ASTM D422-63
Textural Class	ASA/SSSA, 1986[2]: Method 15-5 Modified Day Hydrometer Method

[1] American Society of Agronomy, Soil Science Society of America, 1982.
[2] American Society of Agronomy, Soil Science Society of America, 1986.

5.2 Compost Samples

Compost for this project was obtained from EKO Compost in Missoula, Montana, one of the four Montana compost suppliers approved by MDT. Two composite samples were collected from the compost stockpile located at the MDT's Crystal Creek maintenance facility. Each sample consisted of approximately 20 subsamples taken from all portions of the stockpile. Subsample sites were different for each composite sample (approximately 40 individual subsample sites for the two samples).

Table 9. Compost sample analyses and methods.

Analysis	Method
Sample Preparation	Test Methods for the Examination of Composting and Compost[1] (TMECC) method 02.02
Total Solids and Moisture	TMECC method 03.09, ASA/SSSA 21-2.2 (1986)
pH	TMECC method 04.11
Electrical Conductivity	TMECC method 04.10
N	TMECC method 04.02
C	TMECC method 04.01-A

[1] U.S.Department of Agriculture and The United States Composting Council, 2001.

6.0 References

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APPENDICES

Appendix A-1
Analytical Data

Coarse Rock Fragments Analysis, MDT Study   Method ASTM D422-63

Sample	> 2 mm Container tare (g)	Container Tare plus > 2mm fraction (g)	Rock size Max size (cm)	< 2 mm Container tare (g)	Container tare plus < 2mm fraction (g)	% Rock (mass)	
77Plot1	13.50	23.56	1.0	17.36	845.97	1.20	
77Plot2	13.52	15.04	1.0	18.39	837.54	0.19	
77Plot3	13.53	19.92	1.0	18.39	984.57	0.66	
77Plot4	13.48	56.73	1.0	18.36	821.88	5.11	
77Plot5	13.49	27.42	1.0	18.34	775.4	1.81	
Plot6	13.53	1545.82	7.0	18.40	646.74	70.92[1]	
Plot7	13.57	1486.36	9.0	18.42	897.62	62.62[1]	
Plot8	13.60	1241.83	10.0	18.44	651.06	66.00[1]	
Plot9	13.60	1012.70	8.0	18.46	1115.45	47.66[1]	
Plot10	13.63	1101.06	4.5	18.46	473.79	70.49[1]	
Plot10D	13.68	1142.17	12.0	18.46	429.80	73.29	duplicate

Air dried samples were crushed with a rubber tipped pestle to break down coarse rock fractions.
Sieves were placed on a Ro-Tap for 5 minutes to separate > and < 2 mm fractions
12/1/2003
[1] Actual rock content is in excess of these values as no cobble/boulder size material was included in samples.

MDT Compost Analysis

11/25/2003 dried at 70 deg C				TMECC Method 03.09	ASA/SSSA 21-2.2	TMECC Method 03.09	ASA/SSSA	TMECC
	Container Tare	Container Plus Wet Compost	Container Plus Oven Dry Compost	Gravimetric Water (as received basis)	Gravimetric Water (dry basis)	Total Solids (wet basis)	% of total sample (> 4.75 mm plus < 4.75mm), Dry weight basis	% of total sample (> 4.75 mm plus < 4.75mm), Wet weight basis
Sample	(g)	(g)	(g)	(%)	(%)	(%)	(%)	(%)
C-1 >4.75mm	8.93	64.48	47.13	31.23	45.42	68.77	15.29	12.78
C-1 <4.75mm	8.82	387.88	220.52	44.15	79.06	55.85	84.71	87.22
C-1 (all)	8.89	352.92	200.36	44.34	79.68	55.66		

Water determined after drying in oven for 24+ hours at 70 deg C.
Reported as g/g wet basis per Test Methods for the Examination of Composting and Compost (TMECC, 2002) and Gardner (ASA, 1986) method for water content in soil as % of dry mass of soil
11/25/2003
Analyst: Gregory Vandeberg, RRU Laboratory